Shaping electron beam using magnetic vortex

Zheng, C.[1], Petersen, T.[2], Kirmse, H.[3], Neumann, W.[3], Morgan, M.[2] and Etheridge, J.[1]

[1] Monash Centre for Electron Microscopy, Monash Univesity, Australia, [2] School of Physics and Astronomy, Monash University, Australia, [3] Department of Physics, Humboldt University of Berlin, Germany

A common approach to reveal atomic structure in condensed matter is to use a highly focused Ångström-sized convergent electron beam, incident upon a sample in a scanning transmission electron microscope (STEM). Recently, several new types of electron probes such as vortex beams, Airy beams and Bessel beams have been generated for STEM. By tailoring electron waves to create these different probe shapes and alternative specimen interactions, several novel applications are revealed, including manipulation of nanoparticles [1], the detection of surface plasmon polariton symmetries [2], and the characterization of Landau states [3] and chiral specimens [4]. Here we present a new approach to shape electron beams by modulating electron phase using a magnetic vortex. We illustrate this approach with the successful generation of an electron Bessel beam with high efficiency [5].

We show that a naturally occurring circular magnetic vortex in a soft-magnetic nanocrystalline thin film creates a conical phase shift for fast electrons, which is equivalent to an ideal light-optical axicon. An efficient non-diffracting electron Bessel beam is generated with this novel electron axicon lens. This highlights the potential for using magnetic nanostructures as highly efficient and flexible phase plates for crafting desired electron beam shapes. In addition, a magnetic vortex of fixed chirality can only focus the electrons from one direction and defocus electrons from the opposite direction. This indicates that such a magnetic lens could also act as a diode device for high energy electrons in future applications.

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